AMENDMENTS TO THE SPECIFICATION:

Page 1, please add the following new paragraphs before paragraph [0001]:

[0000.2] CROSS-REFERENCE TO RELATED APPLICATIONS

[0000.4] This application is a 35 USC 371 application of PCT/DE 03/01350 filed on April 25, 2003.

[0000.6] BACKGROUND OF THE INVENTION

Please replace paragraph [0001] with the following amended paragraph:

[0001] ~~Prior Art~~ **Field of the Invention**

Please replace paragraph [0002] with the following amended paragraph:

[0002] The invention is ~~based on a~~ **directed to an improved** fuel injection valve for internal combustion engines. ~~of the kind known from the prior art. For instance, International Patent Disclosure WO 96/19661 shows a fuel injection valve with a valve body, in which a bore is embodied that is defined on its end toward the combustion chamber by a conical valve seat. A pistonlike valve needle is disposed longitudinally displaceably in the bore and has an essentially conical valve sealing face on its end toward the combustion chamber. The valve sealing face is divided into two conical faces, which are divided from one another by an annular groove. The opening angle of the two conical faces and the opening of the conical valve seat are adapted to one another in such a way that upon contact of the valve needle with the valve seat, the edge that is embodied at the transition from the annular groove to the first conical face comes to rest on the valve seat and acts as a sealing edge, in order to control the flow of fuel to at least one injection opening that originates at the valve seat and discharges into the combustion chamber of the engine.~~

Please add the following new paragraph after paragraph [0002]:

[0002.2] Description of the Prior Art

Please add the following new paragraph after paragraph [0002.2]:

[0002.4] International Patent Disclosure WO 96/19661 shows a fuel injection valve with a valve body, in which a bore is embodied that is defined on its end toward the combustion chamber by a conical valve seat. A pistonlike valve needle is disposed longitudinally displaceably in the bore and has an essentially conical valve sealing face on its end toward the combustion chamber. The valve sealing face is separated into two conical faces, which are ~~divided~~ **separated** from one another by an annular groove. The opening angle of the two conical faces and the opening of the conical valve seat are adapted to one another in such a way that upon contact of the valve needle with the valve seat, the edge that is embodied at the transition from the annular groove to the first conical face comes to rest on the valve seat and acts as a sealing edge, in order to control the flow of fuel to at least one injection opening that originates at the valve seat and discharges into the combustion chamber of the engine.

Page 2, please replace paragraph [0005] with the following amended paragraph:

[0005] ~~Advantages of the Invention~~

SUMMARY AND ADVANTAGES OF THE INVENTION

Please replace paragraph [0006] with the following amended paragraph:

[0006] The fuel injection valve of the invention ~~having the definitive characteristics of claim 1~~ has the advantage over the prior art that the opening dynamics of the valve needle remain constant over its entire service life. To that end, recesses are embodied on the valve sealing face that hydraulically connect the annular groove with a portion of the second conical face located on the combustion chamber side of the annular groove. In the partial stroke range of the valve needle, no additional fuel pressure can therefore build up in the annular groove, since the fuel is diverted through the recesses into the chamber that is embodied between the

valve seat and the second conical face. This chamber communicates in turn with the combustion chamber via the injection openings, so that reliable pressure relief of the annular groove in the partial stroke range is assured. Not until the maximum stroke is attained does the fuel flow out of the pressure chamber into these regions of the valve sealing face as well and assure the appropriate pressure increase for injection of the fuel into the combustion chamber at high pressure.

Page 3, please delete paragraph [0007].

Please replace paragraph [0008] with the following amended paragraph:

[0008] **Advantageous features of the subject of the invention are disclosed.** In a first advantageous feature, the ~~structure~~ **invention** is embodied as a roughening of the valve sealing face. The roughening is directly adjacent to the annular groove and is thus disposed on the second conical face. Such roughening can be produced in a simple way, either with a laser or by an etching process.

Please replace paragraph [0009] with the following amended paragraph:

[0009] In a further advantageous feature, the recesses are embodied as many **elongated** grooves. By means of a suitable total cross section of the grooves, a suitable cross section at which pressure relief of the annular groove is assured can be attained. These grooves can advantageously be embodied in various ways. It is especially advantageous if the grooves are embodied as microscopic grooves whose depth is less than 50 μm. Such shallow microscopic grooves do not impair the stability of the valve needle in the region of the valve seat, yet nevertheless a suitable cross section that suffices for pressure relief of the annular groove can be attained by way of the number of grooves. It is especially advantageous in this respect if the depth of the grooves is greater than their width, since then the surface area with which the

valve needle can be seated on the valve seat increases for the same flow cross section. This reduces wear in the region of the valve seat and thus lengthens the service life of the fuel injection valve.

Page 4, please replace paragraph [0010] with the following amended paragraph:

[0010] In a further advantageous feature, the structured surface is formed by **elongated** grooves whose end facing away from the combustion chamber is located inside the ~~annular~~ **elongated** groove. Such grooves offer the advantage of being simpler to make. If the ~~annular~~ **elongated** groove begins precisely at the second edge of the ~~annular~~ **elongated** groove, then it is not always possible in the manufacturing process to place the beginning of the **elongated** groove exactly at the second edge. However, if the ~~annular~~ **elongated** groove begins inside the ~~annular~~ **elongated** groove, then the precise position of the end toward the combustion chamber of the **elongated** grooves does not matter.

Please replace paragraph [0011] with the following amended paragraph:

[0011] In a further advantageous feature, the recesses are embodied as many **elongated** grooves which are curved in an S shape. Grooves designed in this way have the advantage of being faster and hence more favorable to produce. In manufacture by a laser process, the needle must be correspondingly rotated so that the laser device will make the groove at the correct point on the valve sealing face. To that end, the valve needle is rotated by a defined angle about its longitudinal axis and remains in this position until the groove has been made by the laser, and then rotates onward again. With grooves curved in an S shape, however, it is possible to rotate the valve needle continuously, so that a curved groove is created in the course of the motion of the laser along the longitudinal axis of the valve needle.

Please replace paragraph [0012] with the following amended paragraph:

[0012] In a further advantageous feature, the width of the **elongated** grooves varies, from their end facing away from the combustion chamber to their end facing toward the combustion chamber. In this respect, it is especially advantageous if the width decreases in that direction. As a result, a rapid diversion of the fuel from the annular groove and a corresponding reduction in throttling at the second edge of the annular groove are attained, and because of the decreasing cross section of the grooves toward the injection openings, the flow conditions between the valve seat and the valve sealing face at least approximately again correspond to those of the known fuel injection valves, so that identical inflow conditions into the **respective** injection openings are also attained.

Page 5, please replace paragraph [0015] with the following amended paragraph:

[0015] ~~A~~ **In a** further fuel injection valve according to the invention, ~~having the definitive characteristics of claim 16, has the same advantage as the fuel injection valve of claim 1. However, in it,~~ the recesses are embodied on the valve seat, and these recesses hydraulically connect the annular groove to a portion of the valve seat located on the combustion chamber side of the annular groove. Hydraulically, these recesses function identically, so that once again a pressure buildup in the annular groove upon a partial stroke of the valve needle is averted.

Please replace paragraph [0016] with the following amended paragraph:

[0016] In an advantageous feature ~~of the subject of claim 16,~~ **this embodiment** the grooves extend between the injection openings, which here begin at the valve seat. As a result, the inflow conditions into the injection openings are unchanged compared to the conventional injection valves ~~until now,~~ so that no adaptation has to be made in this respect. However, it

may also be advantageous to use ~~to use~~ the grooves for a uniform inflow of the fuel into the injection openings. To that end, the grooves extend beyond the injection openings, so that if the valve needle comes to be in a slightly skewed position, the uniform inflow of fuel is not impaired.

Page 6, please delete paragraph [0018].

Please replace paragraph [0019] with the following amended paragraph:

[0019] ~~Drawing~~ **BRIEF DESCRIPTION OF THE DRAWINGS**

Please replace paragraph [0020] with the following amended paragraph:

[0020] ~~In the drawing, a fuel injection valve of the invention is shown. Shown are~~ **Other features and advantages of the invention will become apparent from the description contained herein below, taken in conjunction with the drawings, in which:**

Please replace paragraph [0021] with the following amended paragraph:

[0021] Fig. 1[[,]] **is** a longitudinal section through a fuel injection valve of the invention;

Please replace paragraph [0022] with the following amended paragraph:

[0022] Fig. 2[[,]] **is** an enlargement of the detail marked A in Fig. 1;

Please replace paragraph [0024] with the following amended paragraph:

[0024] Fig. 4a and Fig. 4b[[, a]] **are** cross ~~section~~ **sections** through a part of the valve needle in the region of a groove;

Page 7, please replace paragraph [0025] with the following amended paragraph:

[0025] Fig. 5, Fig. 6 ~~and~~ Fig. 7[[,]] and Fig. 8 show the same detail as Fig. 2 for further exemplary embodiments;

Please delete paragraph [0026].

Please replace paragraph [0027] with the following amended paragraph:

[0027] Fig. 9, once again, **shows** the same detail as Fig. 2, but here the valve body is slightly modified on its end toward the combustion chamber compared with the embodiment shown in Fig. 1;

Please replace paragraph [0033] with the following amended paragraph:

[0033] ~~Description of the Exemplary Invention~~

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Please replace paragraph [0034] with the following amended paragraph:

[0034] Fig. 1 shows a fuel injection valve of the invention in longitudinal section. In a valve body 1, a bore 3 is embodied that is defined on its end toward the combustion chamber by a conical valve seat 12. At least one injection opening 14 extends away from the valve seat 12 and, in the installed position of the fuel injection valve, it discharges into the combustion chamber of the internal combustion engine. A pistonlike valve needle 5 is disposed longitudinally displaceably in the bore 3 and is guided with a guided portion 105 in a guide portion 103 of the bore 3. Beginning at the guided portion 105 of the valve needle 5, the valve needle 5 narrows toward the valve seat 12, forming a pressure shoulder 7, and at its end toward the combustion chamber it changes over into a valve sealing face 10. In its closing position, the valve needle 5 rests with the valve sealing face 10 on the valve seat 12 and thus closes off the injection openings [[11]] **14** from a pressure chamber 16 embodied between the valve needle 5 and the wall of the bore 3. The pressure chamber 16 is radially widened at the level of the pressure shoulder 7, and an inlet conduit 18 which extends in the valve body 1 and by way of which the pressure chamber 16 can be filled with fuel at high pressure discharges into the radially enlarged part of the pressure chamber 16.

Page 9, please replace paragraph [0037] with the following amended paragraph:

[0037] At the outset of the opening stroke motion of the valve needle 5, a high pressure prevails in the pressure chamber 16 and acts on the first conical face 20, which exerts some of the opening force on the valve needle 5. Immediately after the valve needle 5 lifts from the valve seat 12, a gap is opened up between the sealing edge 27 and the valve seat 12, through which gap fuel flows at high pressure out of the pressure chamber 16 into the annular groove 25, which until then was pressureless, so that the fuel pressure there rises. Although initially a slight annular gap is opened up between the second edge 29 and the valve seat 12, nevertheless because of the recesses 35 a wider flow cross section is available, so that the fuel is rapidly diverted from the annular groove 25, and the pressure rise there is only slight. Not until the further opening stroke motion, when a relatively large gap is opened up between the sealing edge 27 and the valve seat 12 and accordingly also between the second edge 29 and the valve seat 12 does a large amount of fuel flow at high pressure out of the pressure chamber 16 to the injection openings 14, so that a correspondingly high pressure now prevails in the annular groove 25 as well. At this instant, at which the valve needle 5 has completed its maximum opening stroke, the structured surface **produced by recesses** 35 no longer plays any decisive role in the flow conditions. At the onset of the opening stroke motion, because of the recesses 35, the hydraulic force from the pressure rise in the annular groove 25 is absent, so that the opening force is determined solely by the hydraulically effective surface area of the first conical face [[10]] **20**. The maximum opening stroke of the valve needle 5 is, as a rule, no longer than 0.2 mm.

Page 10, please replace paragraph [0038] with the following amended paragraph:

[0038] The recesses 35 in the exemplary embodiment shown in Fig. 2 can be produced by etching, for instance, or by ~~making the recesses 35 by~~ means of a laser, so that a hydraulic communication is established between the annular groove 25 and the second portion of the second conical face 22, that is, the portion located on the combustion chamber side of the annular groove.

Please replace paragraph [0039] with the following amended paragraph:

[0039] In Fig. 3, the same detail as in Fig. 2 is shown, for a different exemplary embodiment. Here the recesses 35 comprise many **elongated** grooves 38, whose end facing away from the combustion chamber coincides with the second edge 29, and which extend as far as a portion, located on the combustion chamber side of the annular groove 25, of the second conical face 22. Given a suitable depth, the **elongated** grooves 38 make an adequate cross section available, leading to a hydraulic relief of the annular groove 25 in the partial stroke range.

Page 11, please replace paragraph [0040] with the following amended paragraph:

[0040] How far the **elongated** groove 38 extend on the second conical face 22 in the direction of the combustion chamber is determined by the differential angle δ_2 and by the location of the injection openings 14. Here the grooves 38 ~~are the grooves 38 extend far enough that they~~ extend beyond the injection openings [[11]] **14**. The grooves 38 are preferably produced in microstructured fashion; that is, they have a depth of preferably less than 50 μm. The width of the grooves 38, which are shown again in Fig. 4a in a cross section of the valve needle 5, is preferably from 5 μm to 50 μm. In order to remove as little material as possible from the second edge 29 as a result of the embodiment of the grooves 38 and thus to reduce the surface area with which the valve needle 5 rests on the valve seat 12 in the

region of the second edge 29, the grooves 38 may be produced with a ratio of their width b to their depth t in which the depth t amounts to from one to ten times the width b. As a result, an only minimal reduction in the surface area is attained in the region of the second edge 29 while preserving the flow cross section that is sufficient to prevent the pressure increase in the annular groove 25 in the partial stroke range. Besides a rectangular cross section, as Fig. 4a shows, it is also possible for instance to produce the grooves 38 with an essentially semicircular cross section, as Fig. 4b shows. Depending on the manufacturing method employed, in general one particular cross section is easier to produce than another, so that whatever is the most favorable for the particular manufacturing process can be chosen.

Please replace paragraph [0041] with the following amended paragraph:

[0041] Fig. 5 shows ~~a further exemplary embodiment, showing~~ the same detail as in Fig. 3 **of a further exemplary embodiment**. The end of the grooves 38 facing away from the combustion chamber is located here inside the annular groove 25, and the grooves 38 extend along the jacket lines of the second conical face 22. The embodiment of such grooves 38 is advantageous in the sense that from the standpoint of manufacture. it is difficult to embody the end of the grooves 38 facing away from the combustion chamber in such a way that it coincides precisely with the second edge 29. By embodying the end of the grooves 38 ~~toward~~ **away from** the combustion chamber approximately in the middle of the annular groove 25, with the grooves 38 extending beyond the second edge 29, problem-free manufacture of the grooves 38 is assured.

Page 12, please replace paragraph [0042] with the following amended paragraph:

[0042] Fig. 6 shows a further exemplary embodiment, showing the same detail as in Fig. 3. The left half of Fig. 6 shows an exemplary embodiment in which the **elongated** grooves 38

are embodied in a curved C or S shape. Such a shape of the grooves 38 is advantageous from the standpoint that in the manufacturing process by means of a laser, the laser beam moves along the jacket lines of the second conical face 22 while the valve needle 5 is at rest. For making rectilinear grooves 38, the valve needle 5 must be kept constantly at rest, until the laser beam [[5]] makes the groove 38. This manufacturing process can be speeded up if the valve needle 5 is rotated continuously and the laser completes its motion under that condition~~, which makes it possible to speed up the manufacturing process~~. The resultant grooves 38 are curved but still meet their purpose of preventing the pressure increase in the annular groove 25. The right half of Fig. 6 shows a further exemplary embodiment in which alternating grooves 38 have different lengths. Since the throttling is to be prevented essentially at the second edge 29 and in the immediate vicinity of the second conical face 22, a large cross section of the grooves 38 in this region is required. In the portions of the second conical face 22 located closer to the combustion chamber, **less** relief by means of the grooves 38 is ~~longer possible to that extent,~~ **required in this area** so that only a few grooves 38 are sufficient there.

Please replace paragraph [0043] with the following amended paragraph:

[0043] In Fig. 7, a further exemplary embodiment is shown, again showing the same detail as in Fig. 3. ~~The left half of Fig. 7 shows an exemplary embodiment in which the grooves 38 have a constant width and extend as far as the end toward the combustion chamber, that is, as far as the end face 32. Depending on the location of the injection openings 14 and the size of the differential angle δ_2, such an embodiment also offers better unthrottling of the annular groove 25. The right half of Fig. 7 shows a further exemplary embodiment, in which~~ **In this embodiment** the grooves 38 have a non-constant width. On the end facing away from the combustion chamber, that is, in the region of the annular groove 25 and of the second edge

29, there is a greater width than at the end toward the combustion chamber of the grooves 38, which assures good unthrottling of the annular groove 25. As an alternative, it may be provided that the grooves 38 have a non-constant depth, with the greatest depth located in the region of the annular groove 25 or at the second edge 29, with the depth of the grooves 38 decreasing continuously toward their end toward the combustion chamber.

Page 14, please replace paragraph [0047] with the following amended paragraph:

[0047] Fig. 10 shows a further exemplary embodiment of a fuel injection valve. Here the valve needle 5 has no recesses on the valve sealing face 10; instead, recesses 35 are embodied on the valve seat 12. The recesses 35 are embodied here as grooves 38, whose end facing away from the combustion chamber is located at the level of the annular groove 25 and which extend as far as the portion of the valve seat 12 located on the combustion chamber side of the annular groove 25. The grooves 38 here are embodied such that they do not intersect the injection openings [[11]] **14** that originate at the valve seat 12. Fig. 11 shows a cross section through Fig. 10 along the line B-B, but the valve needle 5 has not been shown here. The grooves 38 can be seen, distributed in alternation with the injection openings [[11]] **14** over the valve seat 12. For example, three injection openings [[11]] **14** and grooves 38 are shown, but any other number may be provided instead. By means of this embodiment of the grooves 38, the inflow conditions for the injection openings [[11]] **14** are unchanged from the known fuel injection valves, so that a new adaptation need not be performed here.

Page 15, please replace paragraph [0048] with the following amended paragraph:

[0048] In Fig. 12, the same view is shown as in Fig. 10 for a different exemplary embodiment; here the grooves 38 extend not between the injection openings [[11]] **14** but

beyond them. This has a further advantage: A slightly incorrect position of the valve needle 5 can occur in operation of the fuel injection valve causing the valve needle 5 to be slightly off axis and thus preventing the inflow of fuel to one or more of the injection openings ~~11~~ **14**, while the gap between the valve sealing face 10 and the valve seat 12 for the other injection openings [[11]] **14** is too large. The consequence is uneven injection and hence an uneven distribution of fuel in the combustion chamber. By means of the disposition of the grooves 38, each injection opening [[11]] **14** is supplied with fuel in a targeted way, so that skewing of the valve needle 5 has no substantial effect on the quantitative distribution of the fuel among the injection openings [[11]] **14**. Fig. 13 shows a perspective view of the valve body 1 **of Fig. 12** without the valve needle 5, making the course of the grooves 38 on the valve seat 12 more visible.

Page 16, please add the following new paragraph after paragraph [0051]:

[0052] The foregoing relates to a preferred exemplary embodiment of the invention, it being understood that other variants and embodiments thereof are possible within the spirit and scope of the invention, the latter being defined by the appended claims.